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AN EXPERIMENTAL STUDY OF THE STIMULUS-FUNCTION*

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PROBLEM

Despite the fact that the stimulus-response formula is an integral feature of current psychology several writers have recently indicated great dissatisfaction with that formula. Typical is the position of Klüver (11), who writes "that everybody interested in determining the actual responses of an animal as elicited by stimulation must dispose of the stimulus-response formula, since it is not only misleading and incorrect but positively harmful, inasmuch as it keeps us from finding out what the responses of the animal are". This attitude is based upon his studies in "equivalent stimuli" (9, 10, 11).

It is questionable whether this work on "equivalent stimuli" has really taken into account what a stimulus is. Kantor (8) has pointed out that a closer analysis is required of the concept of stimulus-response and has suggested that perhaps we should not regard an object as a stimulus, but rather the stimulus as a function localizable in an object. The assumption may be made that a response or a configuration of action is not correlated with an object but with some function of an object in an interactional situation. An experimental demonstration of the Stimulus-Function of objects is found in the well known conditioned reflex experiments of Pavlov (18). The Stimulus-Function inherent in a piece of meat in the case of a dog is transferred or built up in a metronome sound, a buzzer, a black square, etc., so that these latter contain functional stimuli that elicit a salivary response.

Before proceeding to a more detailed description of the present problem it is well to consider the lines of work which may be regarded as its background. There are in general three of these: (1) Certain studies in the general field of learning; (2) Experimentation to determine "brain mechanisms"; (3) And the more recent work on "equivalent stimuli".

(1) The first class includes studies which bear on what Köhler has called the "Transposition" phenomenon. Hunter (5) trained rats to make discriminatory reactions to sound and silence and found that some of the animals reacted correspondingly to substitutions of light and darkness. Watson and Watson (23) negatively conditioned a child to a rat and found that it made almost equally intense

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fear reactions to a dog, a pigeon, a fur collar and a Santa Claus mask. Lashley (14) trained animals to react positively to one of two "stimuli" and found the animal would react correspondingly to a stimulus of a new pair of the same class. Köhler (12, pps. 216-217, 302-303), in his "transposition" experiments, found that chicks trained to react positively to medium gray when medium and light gray were presented, responded positively to dark gray when dark and medium gray were presented. He obtained substantially the same results with apes when they were presented with sizes and hues. Dunlap, Gentry, and Zeigler (2) report that when rats are trained to move between two adjoining compartments in response to electric shocks the same behavior is elicited by auditory stimulation. Wheeler and Perkins (20) have reviewed several studies (4, 13, 21) similar to Köhler's work in "transposition".

(2) The second class of studies were made with the avowed intention of gaining a more detailed picture of what has been called "brain mechanisms". Pavlov (19), working with dogs, found what he called "initial generalization", namely, that there is a smaller excitatory effect with an increase of distance from the point of original stimulus. Loucks (18), in a recent critical repetition and revision of Pavlov's work, finds no evidence that the initial stimulation of more distant spots results in smaller secretions than *loci* nearer to the originally conditioned place. Lashley's (15, 16) two well known studies were made with rats and dealt with form discrimination. Klüver's (9, 10, 11) extensive work with monkeys on the "basic mechanisms of animal behavior" will be mentioned later under the heading of "equivalent stimuli". Franz (3) trained subjects to identify given geometric forms when presented to given peripheral areas. After learning, these forms were presented to other peripheral areas equally distant from the fovea and it was found that the results were only slightly affected. Leeper and Leeper (17), interested in proving that learning involved large dynamic neural connections rather than specific ones, presented one group of their subjects with varying stimulational materials (mazes, melodies, rhythms) and the other with stimulus objects which were not varied. They found the rate of learning for the varied and unvaried material was approximately the same.

(3) The third class of studies, on "equivalent stimuli", may in general be said to have grown out of the work of Lashley (14) mentioned above and out of Köhler's "transposition" experiments. Two somewhat different types of procedure have been employed in these "equivalent stimuli" experiments. The first is exemplified in the work of Lashley (15, 16) and Klüver (9, 10, 11), where the subject was trained to respond to one stimulus which after learning was replaced by a different one to determine whether the same reaction would be produced. In this attempt to determine in some

detail the nature of the basic mechanisms in animal behavior, it was found that stimuli may be modified radically without effecting their "equivalence". The second type of procedure is illustrated in the work of Franz (3) on peripheral stimulation mentioned above.

What the Gestaltists (12), Lashley (15), Klüver (11), and Leeper and Leeper (17) mean by "equivalent stimuli" is that different objects elicit the same response within certain limits and under certain conditions. This work and the studies described above demonstrate, as Kantor (6, Ch. II) has held for some time, and as Klüver has more recently pointed out, that there is no definite way of correlating stimulus object with response.

We agree with Klüver and other protestants that the present interpretation of a psychological stimulus as a stimulus object is grossly unsatisfactory, but we feel that a reinterpretation of what is meant by the stimulus-response mechanism is required. The present study is directed generally at an analysis of the fundamental stimulus-response phenomenon in human behavior. Specifically, this is an attempt to obtain a more adequate description of psychological stimuli in terms of Stimulus-Functions rather than in terms of stimulus objects. It is our observation that a stimulus-response situation is essentially a single behavioral phenomenon. Obviously, any analysis of this phenomenon is a logical or artificial one, the value of which depends upon its adequacy as logical technique for handling psychological data.

On casual observation the single behavioral situation involves a biological organism functioning as a whole and stimulus objects with physical properties. Closer observation reveals that when the organism functions psychologically (as distinguished from its physiological functioning) it does so in relation to an experiential history that genetically endows the physical stimulus and its properties with a functional stimulus value. The fundamental stimulus-response mechanism involved in psychological phenomena is conceived as a dynamic interactional affair between the responding biological organism with an experiential history and the object which is a *locus* for the stimulus function.

It is the validity of this working hypothesis that we have attempted to investigate. To this end stimulus-response phenomena were contrived in the laboratory using human subjects and carefully prepared stimulus symbols unfamiliar to the subjects. These were brought together under laboratory conditions of interaction, so that prescribed psychological stimulus-response phenomena were set up. An attempt was made to investigate the *locus* of the Stimulus-Functions as set up in nonsense stimulus symbols. Investigated were the extent to which the several stimulus symbols could be modified before established stimulus-response relations were affected. This was done under two conditions: (1) the progressive varying of

learned stimulus symbols to points at which the prescribed functional stimuli broke down or failed to operate; and (2) the progressive varying of inoperative stimulus symbols back to points where the prescribed functional stimuli resumed operation.

EXPERIMENTAL

Half of the stimulus symbols used were arbitrarily designated as "right" and the other half, mirror images of these, as "wrong". These materials are shown in Fig. 1. Between these opposite stimuli and human subjects a prescribed response ⟷ stimulus-function situation was to be contrived. The peculiar needs of the problem called for varying the "right" stimulus symbols until they no longer operated as in the learning situation. It is this point of breakdown in response that we would regard as demonstrating the *locus* of the Stimulus-Function.

The experiment was divided into two parts. The first part consisted of a learning situation, during which the five "right" and five "wrong" symbols were presented to the subject. The second, was a testing situation, in which only the "right" material of the learning situation was presented with gradient variations of this material. This testing situation was divided into two parts. The first began with a presentation of "right" symbols followed by seven gradient variations of each (see Fig. 2). In the second the same materials were presented but in exactly the reverse order, e. g., the most extreme variations of the "right" symbols were presented first and gradiently varied back to the originals.

The learning series symbols were presented in the following chance order: 1, 3, *4*, 2, *5*, 3, 4, *5*, *1*, *2*, 3, *4*, *5*, 1, 4, 2, *1*, *5*, 2, 3, *5*, 2, *1*, 4, 3, *2*, 1, *4*, 3, *5*, 2, 1, 2, *4*, *5*, 3, *1*, 4, 3, *5*. Italicised numbers indicate "wrong" symbols. The gradient, but chance, order of the test series of symbols was as follows:

0	1	2	3
4, 1, 5, 2, 3	1, 4, 2, 5, 3	2, 5, 1, 3, 4	2, 3, 1, 5, 4
4	**5**	**6**	**7**
3, 1, 4, 2, 5	2, 4, 1, 3, 5	2, 1, 4, 3, 5	2, 1, 3, 4, 5

Digits above the bar are variation numbers and those below are symbol numbers. The symbols were drawn in black india ink on a belt of kymograph paper and each occupied a 24 by 29.5 mm. field.

To meet the mechanical requirements of this experiment a special presentation apparatus was constructed for presenting both the learning and test series of symbols. (This apparatus was later elaborated for a more extended research and is described in Carter (1).) This piece permitted the intermittent presentation of symbols one at a time by a half second flash of illumination. Each symbol was followed in one second by a half-second "buzz" (oscillator tone) and a three-second interval then intervened before the next presentation. The apparatus provided that the "buzz" could be eliminated

FIGURE 1

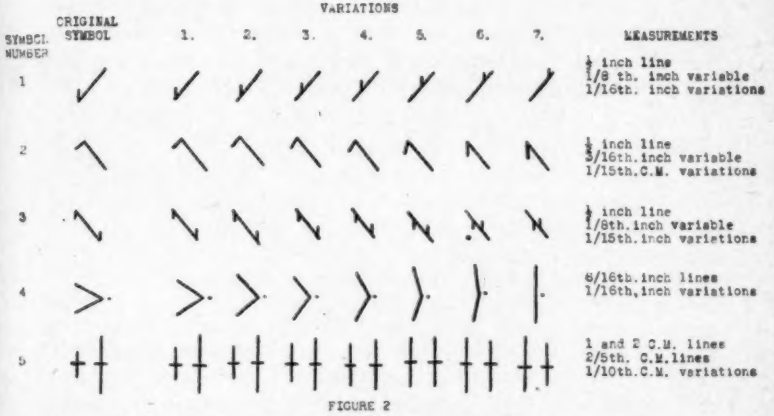

FIGURE 2

by pressing a response key after "right" symbol presentations but not after "wrong" symbol presentations. In this manner differential responses to "right" and "wrong" symbols could be made by the subject.

The subjects used in this experiment were 29 university students ignorant of the nature and purpose of the experiment. Each was introduced into a semi-dark room and seated before the apparatus. The subject read printed instructions and was then handed the ear phones and directed to the response key on the table before him.

The lights were turned out and at the signal "ready" a three-minute trial period was begun. After this trial period the presentations were stopped and the subject was directed to reread the instructions. He was then asked if he understood what he was to do. Any questions were answered as nearly as possible in the exact language of the printed instructions.

At the signal "ready" the presentation of the learning series of symbols was begun and continued until the subject reported that he had learned to make responses to the "right" symbols only. It was considered that learning had taken place if the subject could go thru four consecutive presentations of all ten symbols each in a varying order without responding to any of the "wrong" or failing to respond to the "right" symbols.

Having learned to make a rapid positive response to the "right" symbols only, the subject was given printed instructions for the test situation and was told that there would be no "buzz" from then on but that he was to respond as he had been doing. The subject wore the earphones all thru the test situation.

At the signal "ready", the presentation of the first part of the test or breakdown series began and the subject's responses were recorded. The second part of the test series—namely the pick-up series—was then presented and all responses recorded.

When on a few occasions a subject asked any question during either of the test series only one answer was given, namely, "Respond only to the right symbols you have learned." In no case was the subject allowed to stop or miss the presentation of a symbol. In the few cases where the subject looked up or showed any signs of stopping he was commanded to "go ahead" or "continue", and if he then hesitated he was told, "Respond only to the right symbols you have learned."

After the test series had been presented, the subject was asked, "At the time you responded to a symbol, did you think it was the right symbol?" In the few cases where there was a negative answer the subject was asked, "Although you noticed some change in the symbol (or symbols) you responded to, did you feel an impulse to respond anyway?" and in every case the answer was "yes". This information was noted on the data sheet along with other information obtained from the subject.

RESULTS

The results of the Learning Series, being only incidental to the purpose of this study, are omitted. Our results are from only the Breakdown (First) and Pickup (Second) Test Series.

These results for 29 subjects represent a single critical presentation in each of the two test series. In the Breakdown Series the individual subjects were presented first with the five "right" symbols (Figure 2) and then with the variations of these five symbols, in the order shown on page ??. The order in each variation was chance and different from that of any other variation. In the Pickup Series the same material used in the Breakdown Series was presented in exactly the reverse order. For instance, the seventh variation with the five symbols in reverse order was presented first, then the sixth variation and so on through the five original "right" symbols previously described.

Although, the data and results obtained in this study are presented collectively through the media of graphs and tables one should not lose sight of the need to consider the results of the individual subjects. The very nature of our problem requires an emphasis on individual performances rather than a statistical handling of group data. With this in mind we present group results only for the purpose of comparison and orientation.

The percentages of the 29 subjects responding to the presented material in the two test series are presented graphically in Figures 3, 4, 5, 6 and 7. It will be noticed in the case of each symbol that a comparison of the curves of the two series show that the curve for the Pickup Series is consistently to the left of that of the Breakdown Series, which indicates that the subjects as a whole responded to more variations of the Breakdown Series than they did in the Pickup Series.

Table 1 indicates the number of subjects responding to the different variations of the 5 original "right" symbols in both test series. In Table 2 is presented the number of subjects initially breaking down in response and picking up the response (first and second test series respectively) in each of the seven variations of the 5 original symbols. Figures 3, 4, 5, 6 and 7 present these results in terms of percentages.

TABLE NO. 1

NUMBER OF RESPONSES OF 29 SUBJECTS TO THE DIFFERENT VARIATIONS OF THE 5 ORIGINAL "RIGHT SYMBOLS" IN THE FIRST AND SECOND TEST SERIES

Symbols	1		2		3		4		5	
Test Series	1	2	1	2	1	2	1	2	1	2
Variations										
0	29	29	29	29	29	29	29	29	29	29
1	26	15	29	28	27	22	29	29	29	26
2	20	6	29	25	25	9	21	19	29	20
3	10	0	29	16	14	4	12	4	19	10
4	6	0	24	13	7	0	5	1	4	2
5	0	0	21	13	0	0	2	0	0	1
6	0	0	14	10	0	0	1	0	0	0
7	0	0	8	10	0	0	0	0	0	0

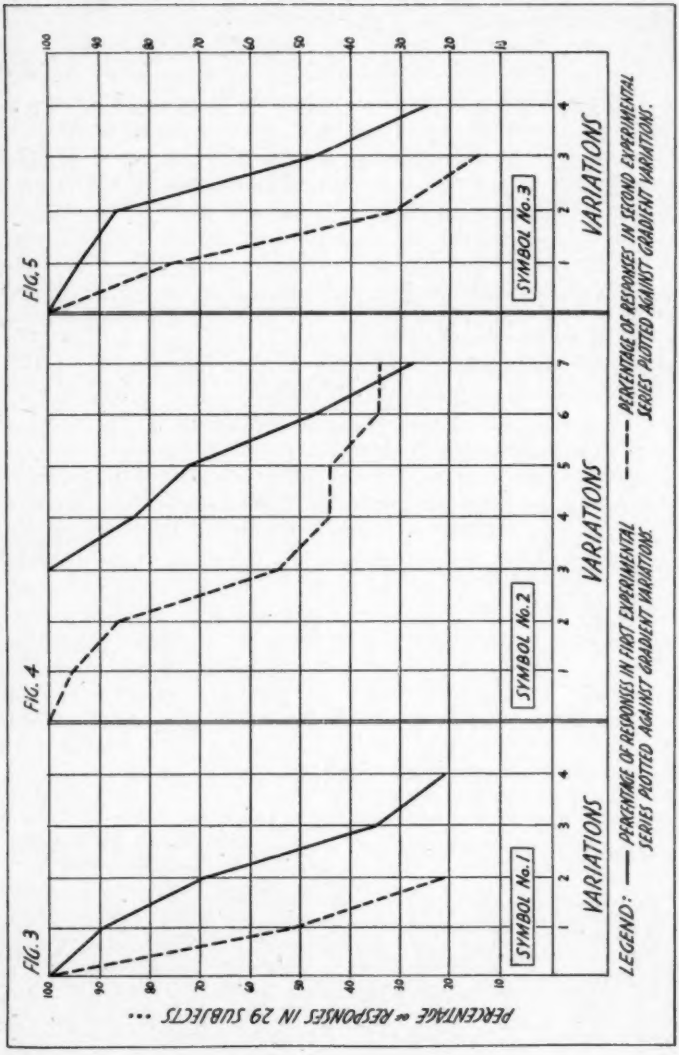
FIG. 3
FIG. 4
FIG. 5
PERCENTAGE = RESPONSES IN 29 SUBJECTS ...
100
90
80
70
60
50
40
30
20
10
SYMBOL No. 1.
SYMBOL No. 2.
SYMBOL No. 3.
VARIATIONS
1 2 3 4
1 2 3 4 5 6 7
LEGEND: —— PERCENTAGE OF RESPONSES IN FIRST EXPERIMENTAL SERIES PLOTTED AGAINST GRADIENT VARIATIONS. ---- PERCENTAGE OF RESPONSES IN SECOND EXPERIMENTAL SERIES PLOTTED AGAINST GRADIENT VARIATIONS.

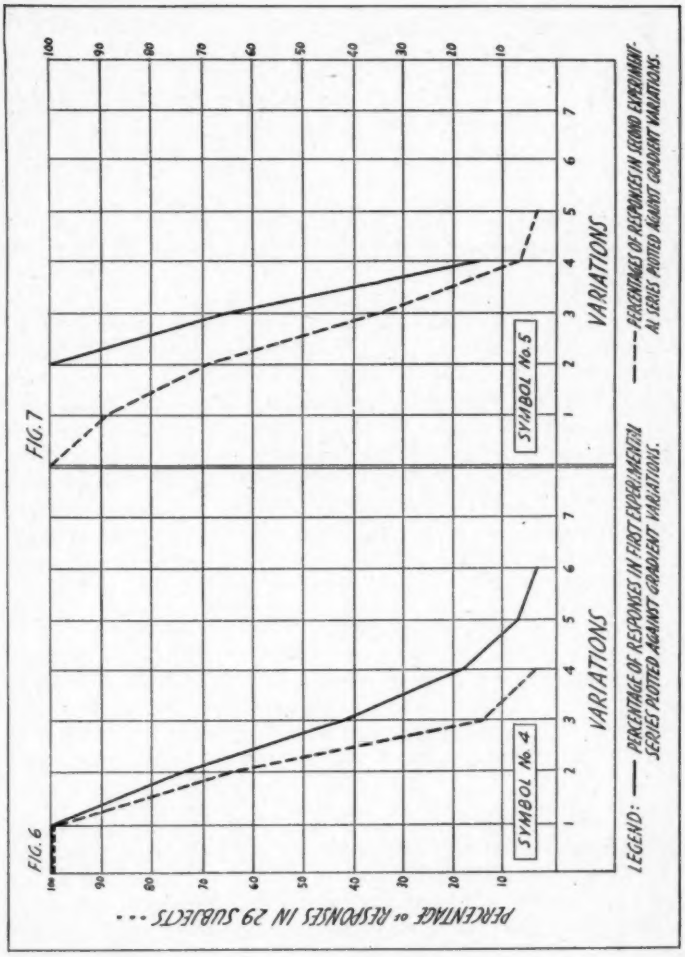
FIG. 6
FIG. 7
PERCENTAGE OF RESPONSES IN 29 SUBJECTS
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7
VARIATIONS
SYMBOL No. 4
SYMBOL No. 5
LEGEND: —— PERCENTAGE OF RESPONSES IN FIRST EXPERIMENTAL SERIES PLOTTED AGAINST GRADIENT VARIATIONS.
– – – PERCENTAGES OF RESPONSES IN SECOND EXPERIMENTAL SERIES PLOTTED AGAINST GRADIENT VARIATIONS.

TABLE NO. 2

NUMBER OF INITIAL RESPONSES OF 29 SUBJECTS TO THE DIFFERENT VARIATIONS OF THE 5 ORIGINAL "RIGHT" SYMBOLS IN THE FIRST AND SECOND TEST SERIES

Symbols	1		2		3		4		5	
Test Series	1	2	1	2	1	2	1	2	1	2
Variations										
0	0	14	0	1	0	7	0	0	0	3
1	3	9	0	3	2	13	0	10	0	6
2	6	6	0	9	2	5	8	15	0	10
3	10	0	0	3	11	4	9	3	10	8
4	4	0	5	0	7	0	7	1	15	1
5	6	0	3	3	7	0	3	0	4	1
6	0	0	7	0	0	0	1	0	0	0
7	0	0	6	10	0	0	1	0	0	0

The linearly interpolated 50 per cent Breakdown and Pickup points for the different variations of the "right" symbols for all 29 subjects are found in Table 3. These were computed by linear interpolation. It will be noted here that there is a positive rank order of correspondence between the Breakdown and Pickup 50 per cent points among the 5 symbol materials. In symbol materials 3 and 4 the 50 per cent points for the Breakdown Series are 2.95 and 2.71 respectively, while in the Pickup Series the corresponding 50 per cent points are 1.58 and 2.3. Except for these two slight inverse instances the rank orders of the 50 per cent points of the two test series correspond exactly. Table 4 represents in rank order the averaged 50 per cent points of the two test series.

From the most extreme variation of each of the several symbols to which each subject responded, averages for the Breakdown and Pickup Series were obtained (Table 5). A positive rank order correlation of .532 was found between the response agreement among the 29 subjects as individuals in the group. This correlation indicates only slight agreement among the subjects as to individual performance.

A positive correlation of .90 was found between the average Breakdown and Pickup points for the 5 symbol materials. This correlation has little significance because only 5 symbols could be used in computing it. As far as it goes however, it indicates a considerable agreement between the points at which, on the average, a symbol "breaks down" and the point at which the average subject "picks up" for the same symbol. This affords proof of the reliability of the procedure of the experiment. That is, a high correlation is found between the average Breakdown and Pickup points for the different symbols regardless of the individual differences among the subjects.

TABLE NO. 3

THE FIFTY PER CENT (LINEAR INTERPOLATION) BREAKDOWN AND PICKUP POINTS OF 29 SUBJECTS FOR THE DIFFERENT VARIATIONS OF THE FIVE ORIGINAL SYMBOLS

Symbols	1			2			3			4			5		
Test Series	1	2	Av.	1	2	Av.	1	2	Av.	1	2	Av.	1	2	Av.
	2.5	1.1	1.8	5.9	3.5	4.7	2.9	1.6	2.3	2.7	2.3	2.5	3.3	2.5	2.9

TABLE NO. 4

ORDER OF AVERAGED BREAKDOWN AND PICKUP POINTS (50 PER CENT POINTS) IN 29 SUBJECTS

Rank Order	1	2	3	4	5
Symbols	2	5	4	3	1
Av. 50% points of 1st and 2nd Test Series	4.7	2.9	2.5	2.3	1.8

TABLE NO. 5

AVERAGE VALUES AND AVERAGE DEVIATION OF THE BREAKDOWN (SERIES 1) AND PICKUP (SERIES 2) POINTS FOR EACH SUBJECT

subject	Average		A. D.	
	Ser. 1	Ser. 2	Ser. 1	Ser. 2
1	4.0	3.4	2.00	1.45
2	3.8	2.2	1.04	0.60
3	1.6	1.4	1.30	1.10
4	2.8	1.8	1.00	0.60
5	3.0	2.0	1.20	0.40
6	2.6	0.4	0.30	0.30
7	3.4	0.8	1.40	0.60
8	3.2	4.0	1.80	1.60
9	4.2	1.8	0.70	1.30
10	3.8	3.4	1.40	1.70
11	3.6	2.2	1.10	1.10
12	3.4	2.4	1.40	1.80
13	4.2	3.2	1.10	1.50
14	3.8	1.6	1.04	0.50
15	3.2	2.4	1.10	1.80
16	2.0	1.4	0.40	0.30
17	2.8	0.8	2.16	0.60
18	2.6	1.8	0.50	1.04
19	3.8	3.2	1.40	1.50
20	2.6	1.2	1.10	0.60
21	2.6	1.8	1.30	0.70
22	3.2	0.4	0.30	0.50
23	3.2	2.0	1.10	0.20
24	1.4	1.4	1.30	1.30
25	2.4	2.0	1.04	1.20
26	4.2	2.2	0.70	1.10
27	2.4	1.8	1.10	0.40
28	3.2	2.8	1.50	1.80
29	1.8	2.0	1.40	2.00

Further facts related to the subject's performance and to the nature of the symbols are evidenced in the average deviations (in Table 5). The average deviations vary considerably from subject to subject, demonstrating thereby, a variation in the performance of the different individuals.

The average deviations computed for the Breakdown and Pickup points of the several symbols (in Table 6) show the relative variation among the gradients of each symbol. On the basis of these average deviations the symbols and their accompanying gradients may be ranked in the order of variability with respect to their highest points of response as follows: (a) for the Breakdown Series 1.2, 1.1, 1.01, .9, and .5 for symbols 2, 4, 1, 3, and 5 respectively; (b) for the Pickup Series 2.1, .9, .8, .7, and .7 for symbols 2, 5, 3, 1, and 4. This means that the subjects were least consistent in the Breakdown Series in the case of symbols 2, 4, and 1 and more consistent in their Breakdown points for symbols 3 and 5.

To the extent that the average deviations of the Breakdown and Pickup points may be considered as measures of the functional stimulus inherence in the symbols, we have a means of evaluating the stimulus material used in this experiment. In this sense we may say symbol 5 and its variations may be considered to have half the functional inherence for the subjects as a whole as has symbol 2 and its variations. (Table 6.)

CONCLUSIONS

This study demonstrates that stimulus objects, to which subjects have learned to make a positive response, can be gradiently varied to points at which the subjects no longer respond.

TABLE NO. 6

AVERAGE VALUES AND AVERAGE DEVIATIONS OF THE BREAKDOWN (SERIES 1) AND PICKUP (SERIES 2) POINTS FOR EACH SYMBOL

Symbol	Average Series		A. D. Series	
	Ser. 1	Ser. 2	Ser. 1	Ser. 2
1	2.14	0.7	1.01	0.7
2	5.40	4.2	1.20	2.1
3	2.60	1.2	0.90	0.8
4	2.50	1.3	1.10	0.7
5	3.00	2.1	0.50	0.9

The results of the Breakdown Test Series show that the original stimulus objects may be varied gradiently to a measurable extent before the subjects break down or reach *loci* beyond which they fail to respond to subsequent variations of the original "right" stimulus symbols.

The results of the Pickup Series (the material of the Breakdown Series in reverse order) show that the subjects begin responding to the variations as they did to the original stimulus-objects.

The discrepancy between the *loci* of responses of the two test

series was due to a difference in the experimental conditions. In the Breakdown Series the subjects were not expecting variations of the "right" symbols. They were expecting presentations of "right" and "wrong" symbols, as in the learning Series. Their only instructions were to respond only to the symbols learned as "right." To some extent they were "caught off guard," to quote the characteristic verbal reports of the subjects. Moreover, the last variations in this series presented to them such extreme differences from the original symbols that a more critical judgment affected their responses in the Pickup Series. From the verbal reports of the subjects it appears that many of them carried over from the Breakdown Series an over-cautious and critical attitude. This obviously inhibited their inclination to respond, in the Second Series, to many variations before they actually did. It seems that all of the subjects, in the case of most symbol material, were over-critical of the Second Series as a result of their experience with the material in the First Series.

We interpret these Breakdown points as *loci* of the stimulus-functions built up by the subjects in the original symbols learned as "right" during the Learning Series. We submit that the results of both test series suggest the functional nature of a psychological stimulus. These stimulus-functions of the original "right" stimulus objects appear to have measurable extent that varies as a function of the experiential biography of the individual subject.

It is our contention that these data tentatively support our thesis that a psychological stimulus is not an object that elicits a one to one response. Rather, it is a function inhering in an object that under given conditions can be demonstrated to have a locus. Beyond this locus any given stimulus object does not have the functional nature necessary to a given psychological response.*

Our present study is only the first approximation of an attempt to investigate experimentally a more adequate description of the stimulus-response concept in psychology. Accordingly, we offer the following tentative conclusions pending further research:

I. Stimulus-Functions appear to have *loci* in terms of symbol variations responded to. This conclusion seems to find support in our results as represented in: (1) the curves obtained from our subjects' responses to the several symbol materials (Figures 3, 4, 5, 6 and 7); (2) the interpolated 50 per cent points in both test series (Tables 3 and 4); (3) and the average deviations computed for the breakdown and pickup points of the several symbol materials (Table 5).

II. The *loci* of Stimulus-Functions appear to be affected by the order difference in which the two test series were presented. Evidence of this is found in: (1) the different thresholds for the same symbol material in the Breakdown and Pickup Series (Table 3); (2) the low correlation between the response results of the two test series, which shows little agreement among the subjects, and the high

correlation between the average subjects' responses which shows a fair agreement; (3) the curves (Figures 3, 4, 5, 6 and 7) which show consistent differences in all symbol material as between the two test series; (4) and the 50 per cent points which also indicate a consistent difference between the two series.

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* We regard psychological stimulus and response as logical abstractions of a single interactional phenomenon.